## §27. Collisionless Particle Confinement Improvement with the Poloidal-angle Independent Magnetic Fields in Helical-Axis Stellarators

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The improvement of collisionless particle confinement are considered systematically based on the model magnetic field, taken W7-X and Heliotron J (H-J) as exmaples.

The role of the radially increasing bumpy field is investigated, which is typically the case for finite beta equilibria in H-J. The following characteristics are given by this bumpy field:

- toroidally-localized Bmin region, where Bmin denotes the minimum magnetic field strength searched along a torus,
- bumpy field has no poloidal angle dependence, which does not affect the radial drift even if its amplitude is enhanced,
- radial variation (here, the increase) enhances the poloidal drift.

The region with larger poloidal drift is well aligned to the region of the local minimum of B with keeping the radial drift unenhanced. In this case, toroidally-localized closed mod-Bmin are formed with the convex radial distribution of B on the equatorial plane around the half of the field period.

On the other hand, the diamagnetic effect is also considered to be the reason for the significant improvement of collisionless particle confinement for finite beta equilibria in W7-X. The magnetic well enhancement (that is the radial increase of the uniform magnetic field component) by the diamagnetic effect for finite beta equilibria is only one significant difference in the magnetic field spectra between vacuum and finite beta cases. Also in this case, the toroidally-localized closed mod-Bmin are formed. The uniform magnetic field also does not have the poloidal angle dependence, whose radial variation can enhance the poloidal drift without enhancing the radial drift. The reason for improvement in W7-X is this poloidal drift enhancement due to the diamagnetic effect for finite beta equilibria. It is noted that the toroidally-localized closed mod-Bmin are formed with the concave radial distribution of B on the equatorial plane around the half of the field period. This is opposite to that caused by the radially increasing bumpy field.

The radially increasing bumpy field and the diamagnetic effect occur simultaneously for typical finite beta equilibria in H-J. Although the toroidally-localized mod-Bmin can be formed, the radial variation of the field strength around this region tends to be weakened with these simultaneous two effects. This is considered as one reason for the weaker improvement in H-J than that in W7-X.

The several ideas can be considered to prevent this unfavorable fact. The one of those ideas is realized with the coil configuration conceptually equivalent to that of H-J. This example configuration, which has a stronger radial increase of the bumpy field even at the vacuum case, is possible with increasing the current in the inner vertical coils. This radial variation is enough to form the toroidally-localized mod-Bmin with the convex radial distribution of B on the equatorial plane around the half of the field period, where local minimum of B locates. The effect of the radially increasing bumpy field overcomes the effect of the diamagnetic effect, which successfully improves the collisionless particle confinement for finite beta equilibrium.

The further improvement and experimental test should be pursued with the real coil configuration based on this systematic study.

Reference:

M.Yokoyama, J.Plasma and Fusion Research, **76**(2000)272.